Pacific Basin Wind Wave Models:

The Generation and Propagation of Low Frequency Energy

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Acknowledgement: Larry Hsu, David Wang (NRL-Stennis)

Ocean Wave Measurement and Analysis

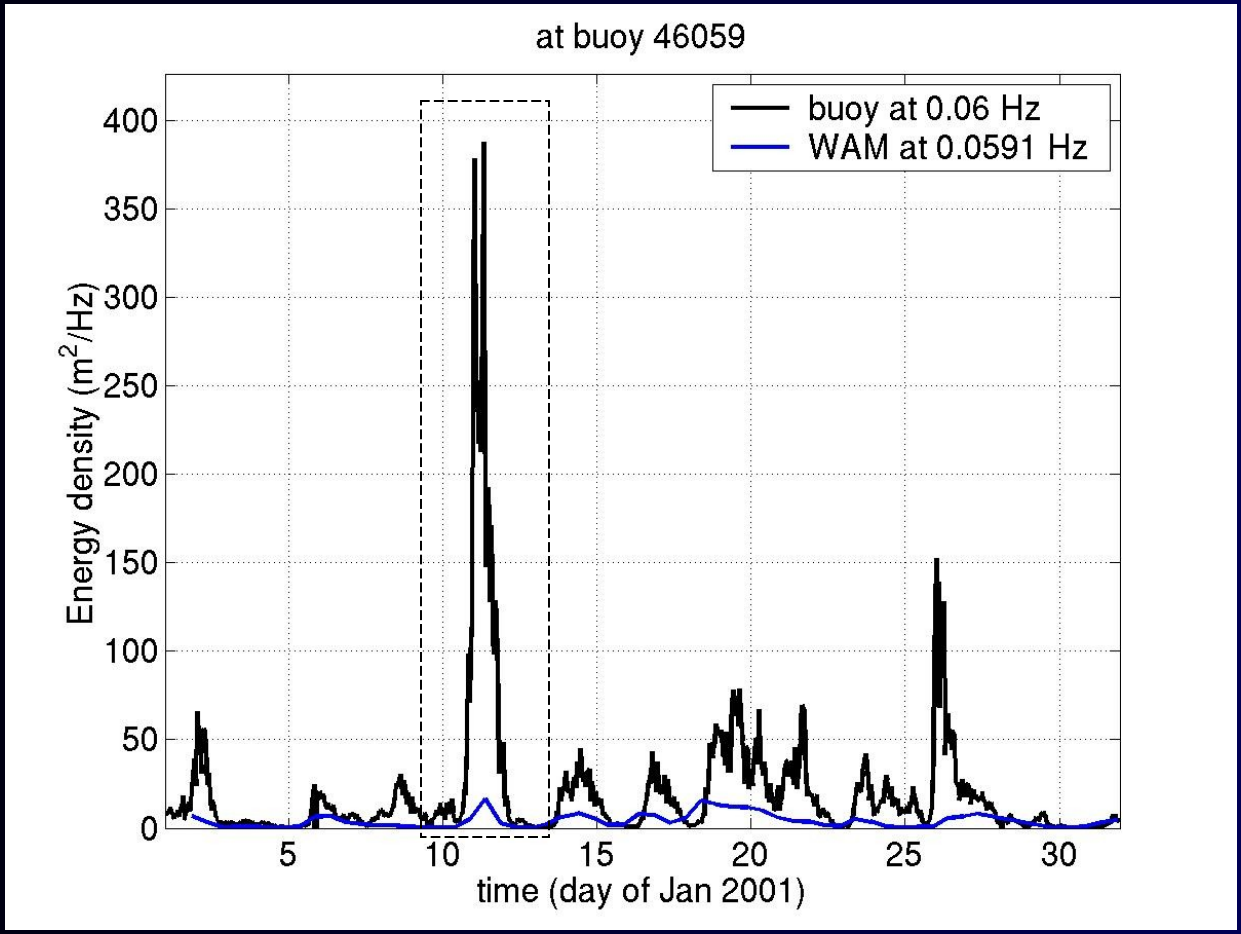
Outline

- WAM: winter swells in California
  - generation problem
- WAM: summer swells in California
  - numerical problem
- simple model
  - numerical problem
  - numerical solution(s)

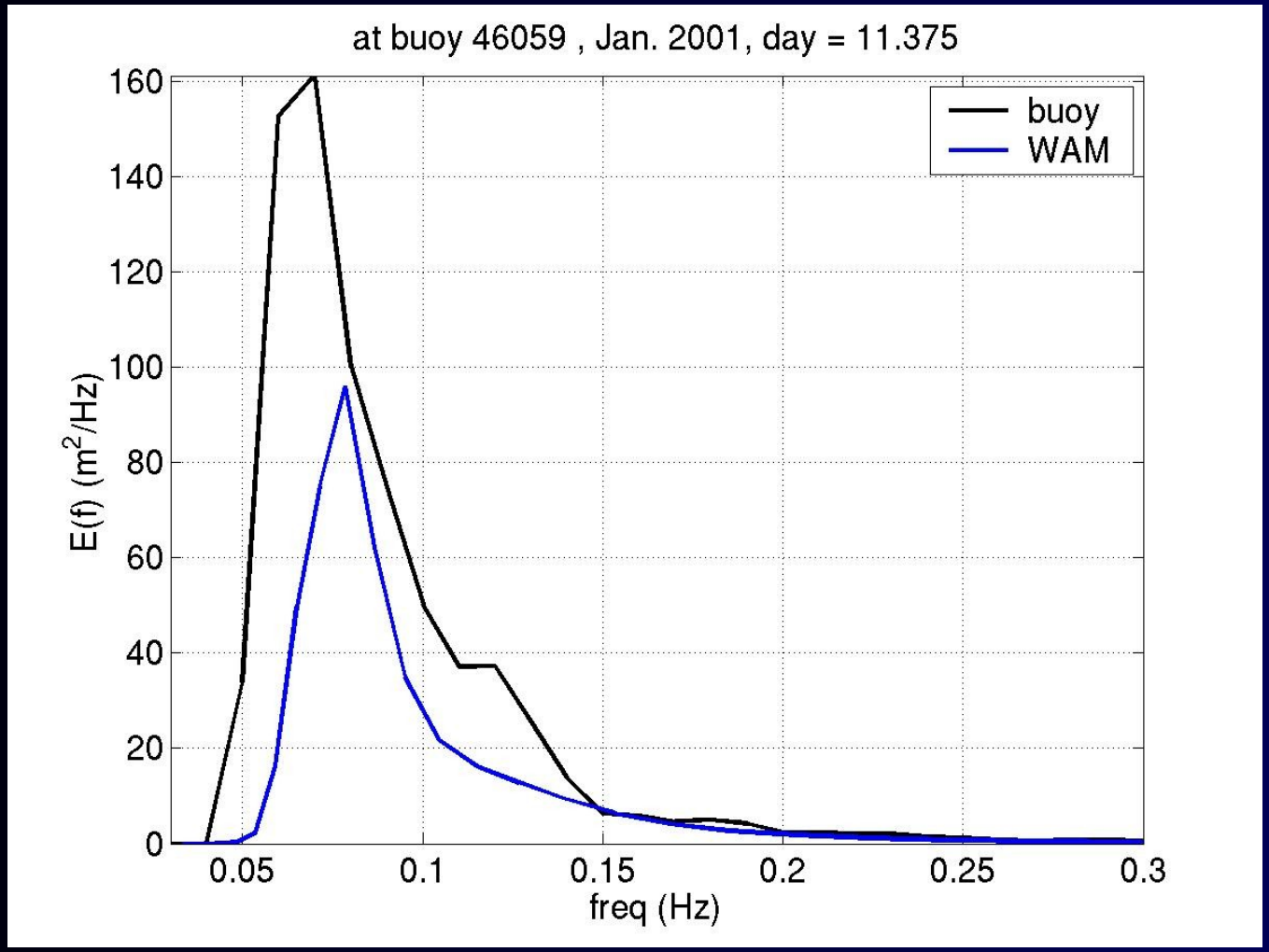
winter swells off CA:

time series: E(0.06Hz), WAM vs. data @ NDBC buoy

(NAVO WAM)



winter swells off CA:
frequency spectrum, 0900Z, Jan 11 2001



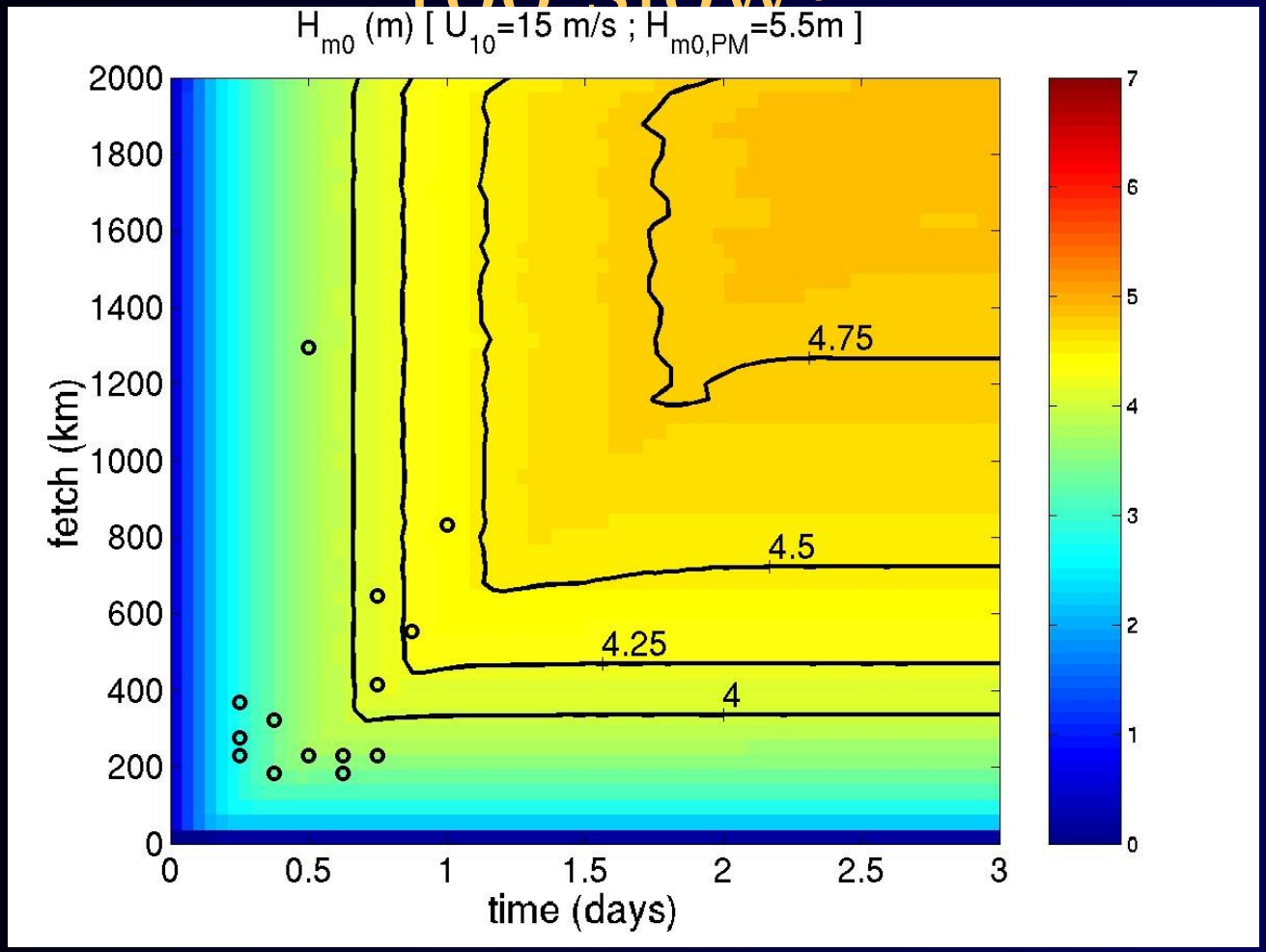
winter swells off CA: WAM

- 0.05 Hz energy shown

winter swells off CA: NOGAPS winds

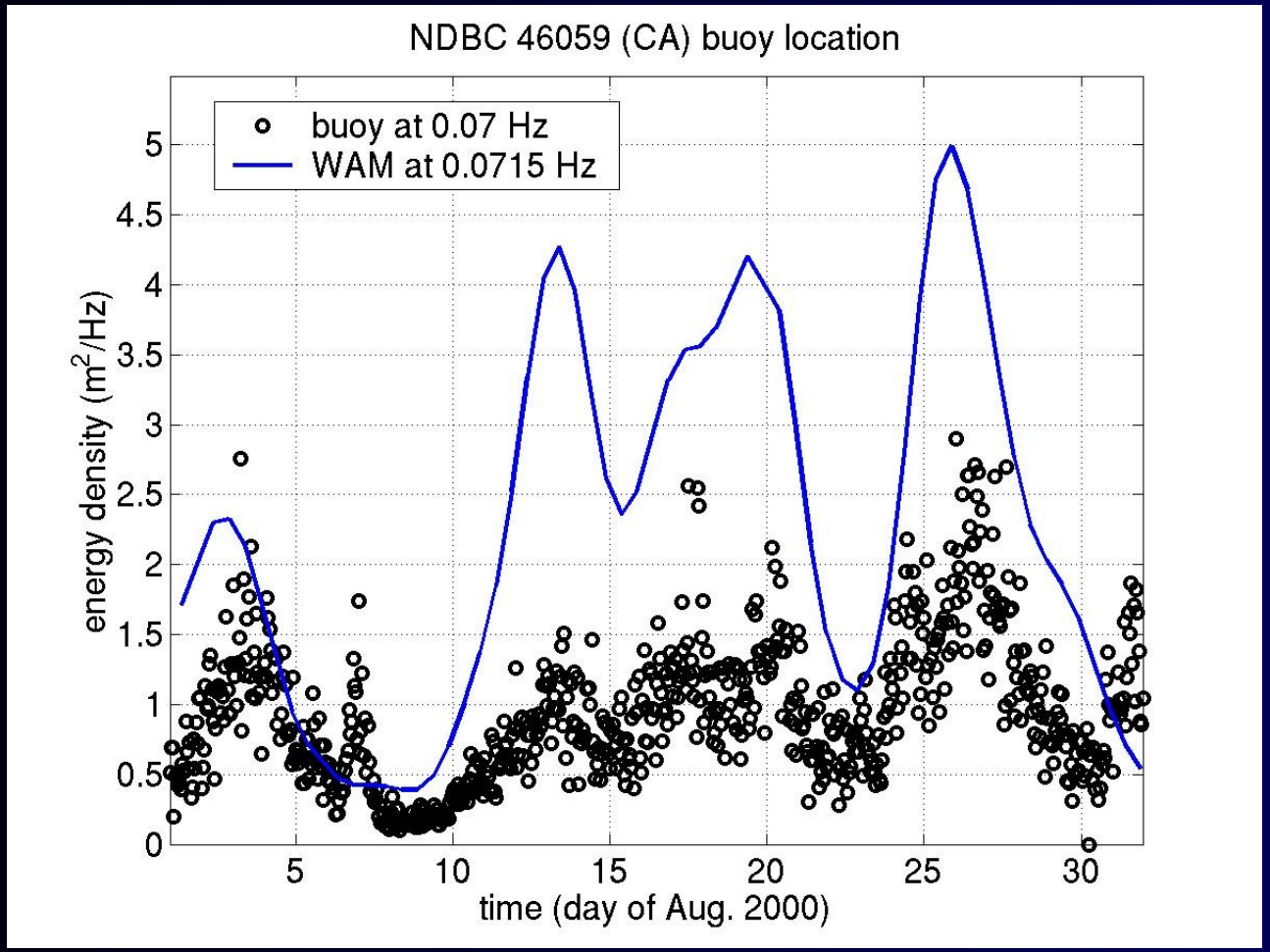
- WAM does not do well with smaller storm because:
  - forcing is wrong (maybe the smaller storm wasn’t really smaller)
  - generation physics in WAM are deficient for smaller storms

Wave model generation stage: too slow?



summer swells off CA:

time series: E(0.07Hz), WAM vs. data @ NDBC buoy

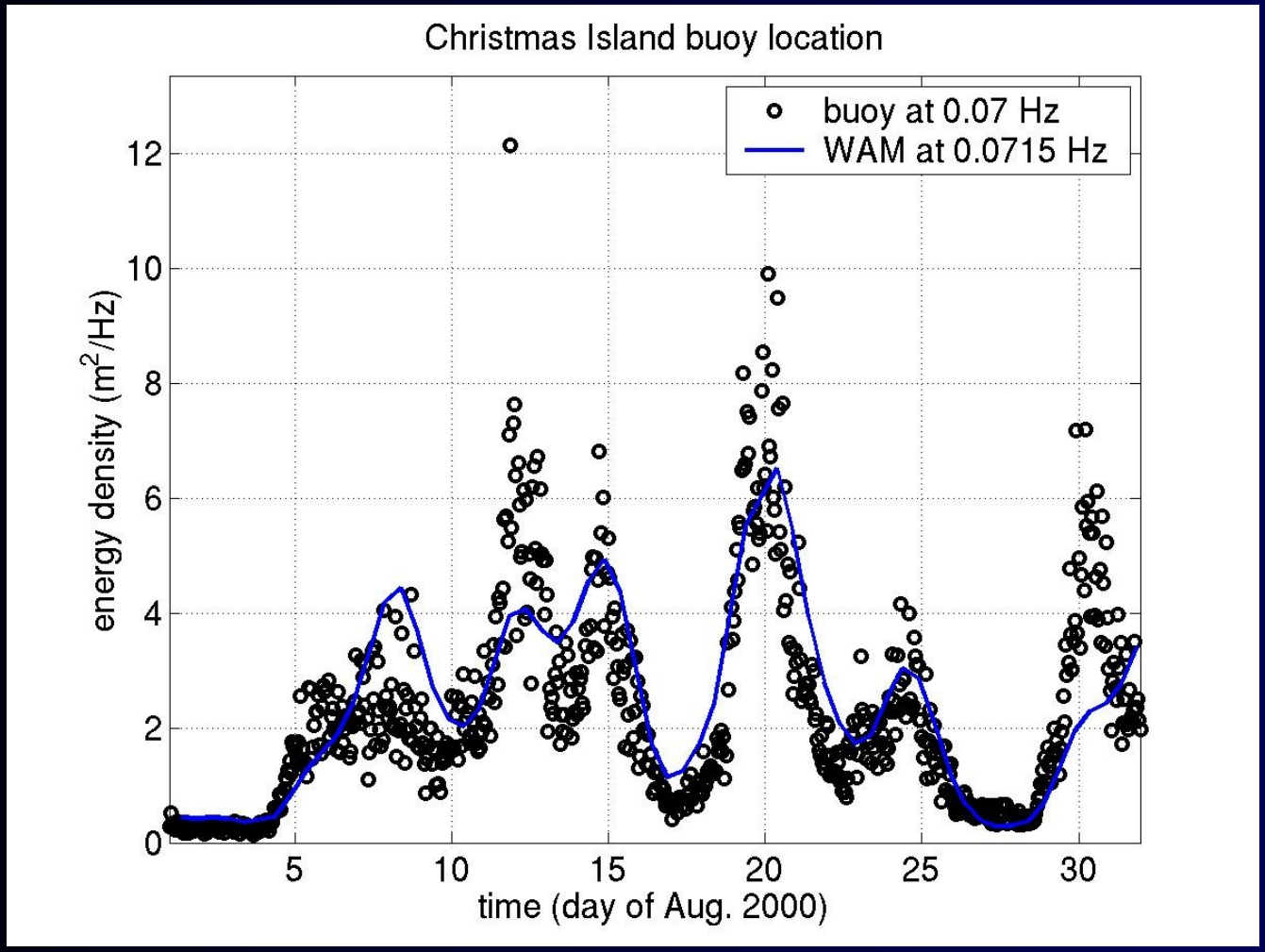


summer swells off CA: WAM

- 0.05 Hz energy shown

summer swells off Hawaii:

time series: E(0.07Hz), WAM vs. data @ NDBC buoy



Objective: represent more islands in Basin-scale model

- one approach: partial transmission past grid points containing sub-grid land masses
- another approach: separate, “perfect propagator” model
- ideal approach: use high resolution
  - requires high resolution everywhere
  - requires accurate numerical scheme
    - requires high *spectral* resolution*

simple model for demonstration

- contains
  - arbitrary wind field $U(x,y,t)$ input
  - blocking by islands
  - 1st generation source/sink term formulation
- doesn’t contain
  - spherical coordinates
  - 3rd generation source/sink terms

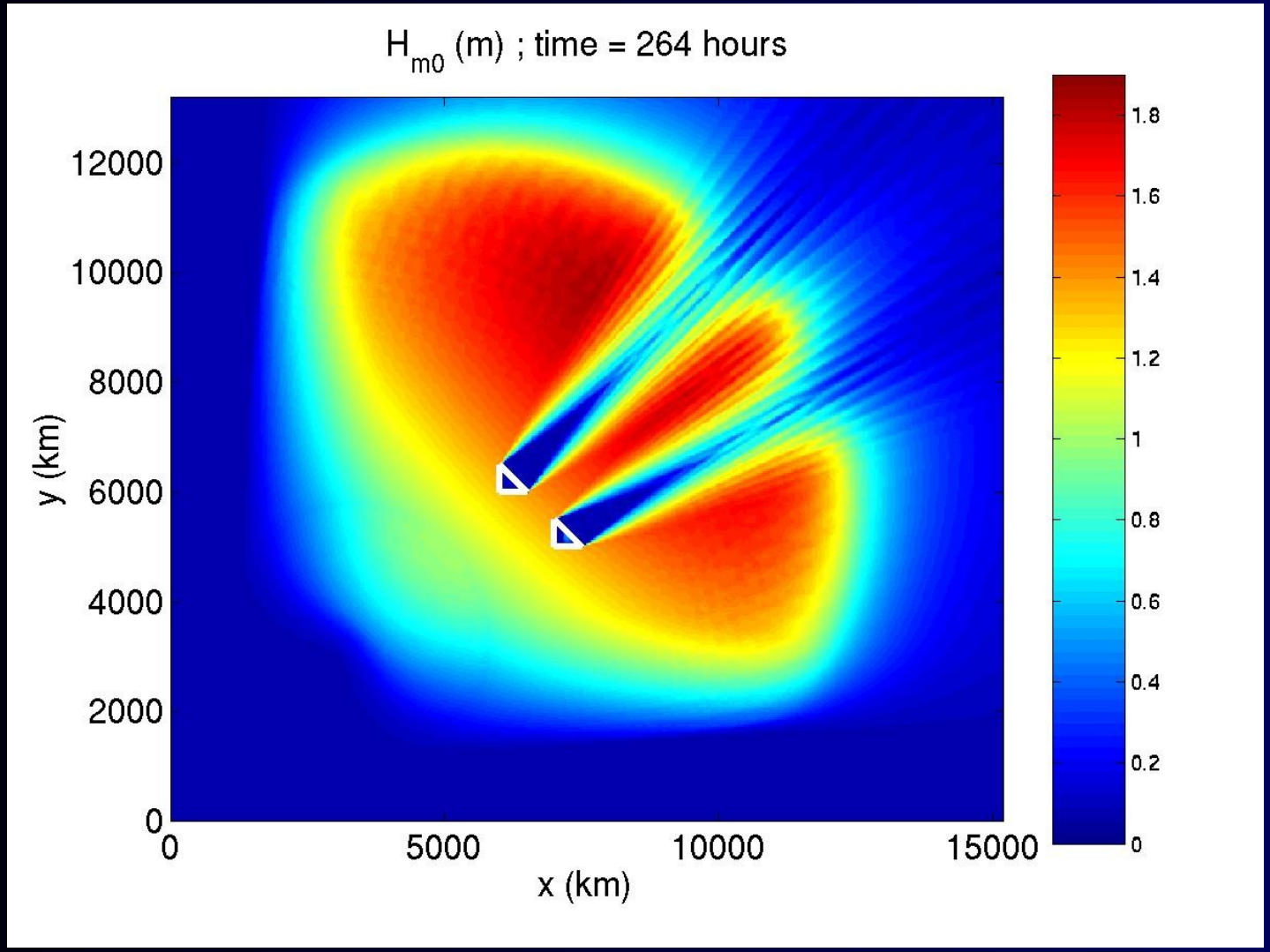
numerical scheme used

- NISL-PG: “non-interpolating” semi-Lagrangian, “product generated”
- references/credits:
  - 1-d version: Olim (1994)
  - 2-d version: H. Petit (Delft Hydraulics), (PG)
- explicit
- accuracy
  - typically similar to “QUICKEST” scheme (WW3)
  - more accurate with larger Δt
- unconditionally stable

rigorous solution
(introduce modeled scenario)

- very fine resolution in four dimensions (x,y,ω,θ) [2.5 degree angular bands]
- some residual θ-GSE, otherwise good representa of “exact” solution.

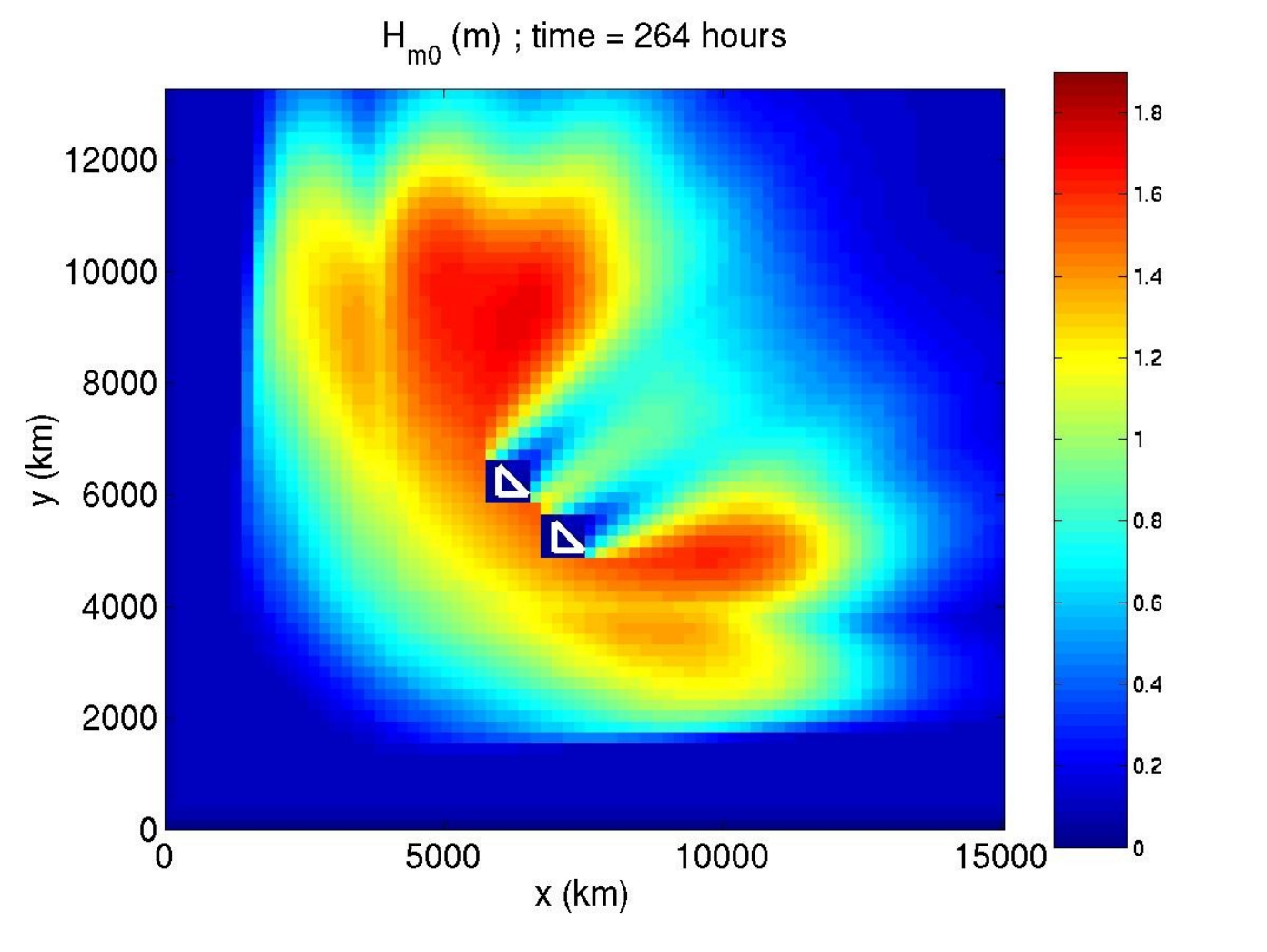
rigorous solution



WAM-like solution

1st order scheme, coarse resolution in all four dimensions (x,y,ω,θ)

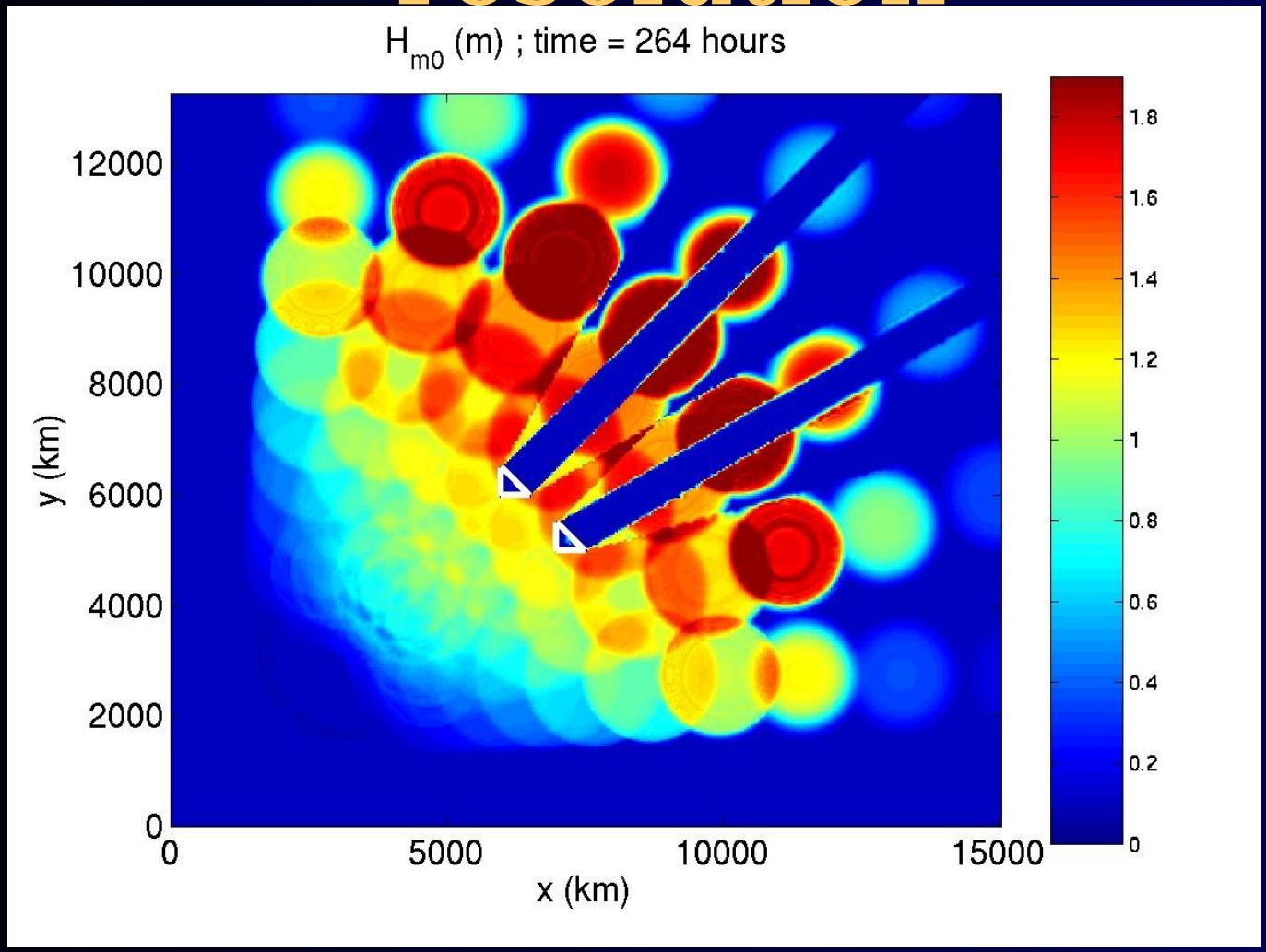
WAM-like solution



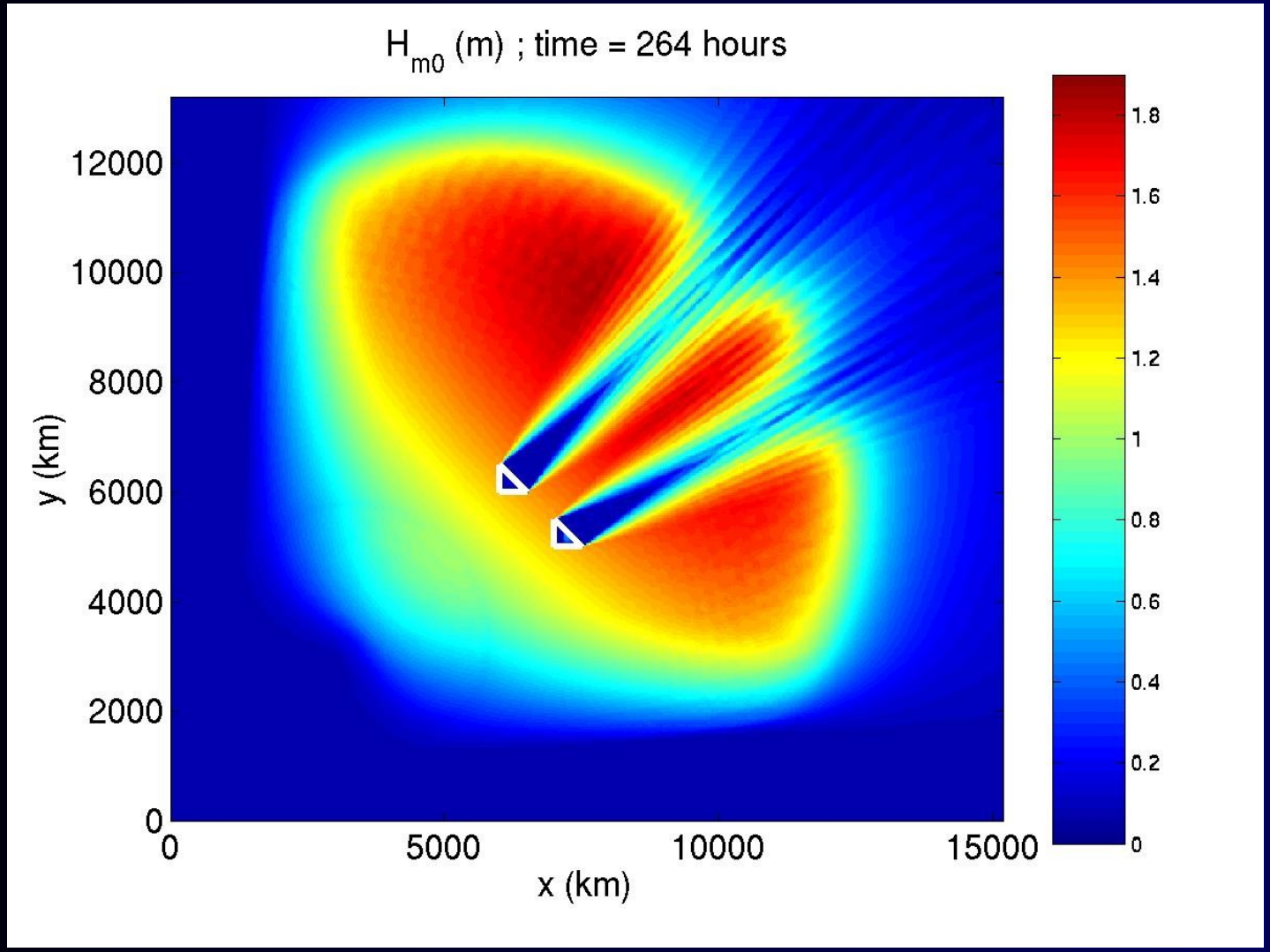
w/high geographic resolution

accurate propagation scheme
coarse resolution in ω , θ dimensions
fine resolution in *x, y* dimensions

w/high geographic resolution



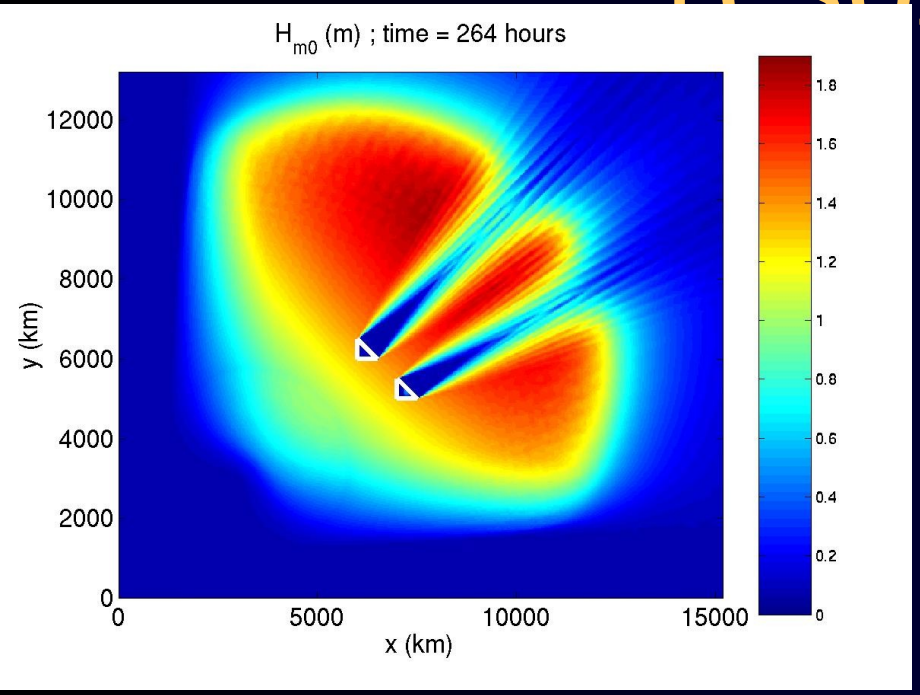
recall the rigorous solution ….



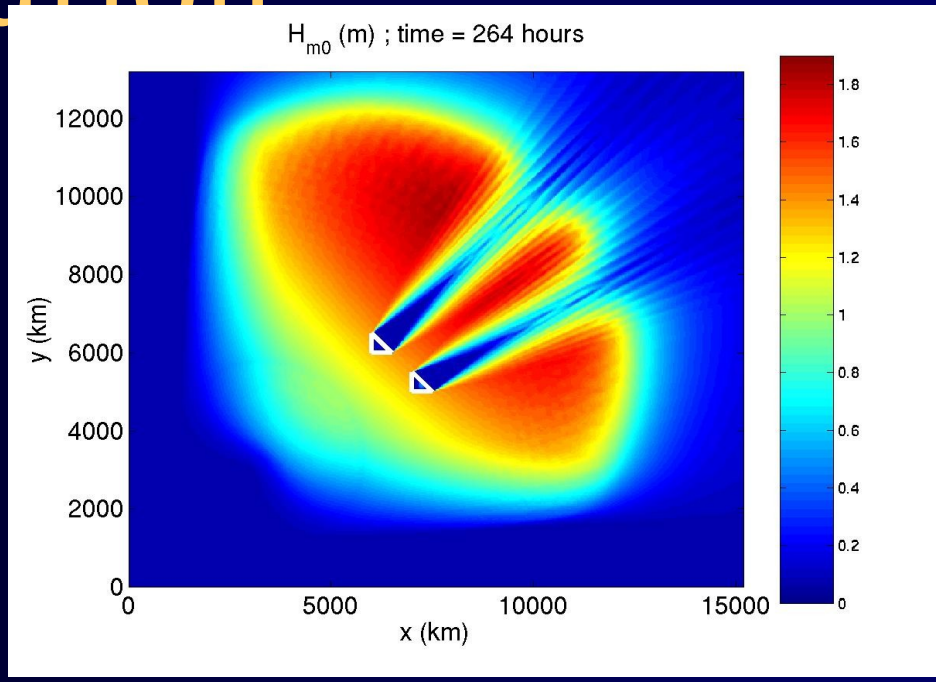
How to get this without excessive cost?

- Exploit:
  - The model does not need high resolution everywhere, all the time.
  - Physics does not need to be rigorously calculated everywhere, all the time.
- Implement simple, hybrid approach:
  - Source terms on coarse grids
  - Propagation on fine grids
  - Transformation as needed (minimize)
  - For swell, omit or simplify physics calculations as appropriate.

Fine geographic resolution, hybrid spectral resolution

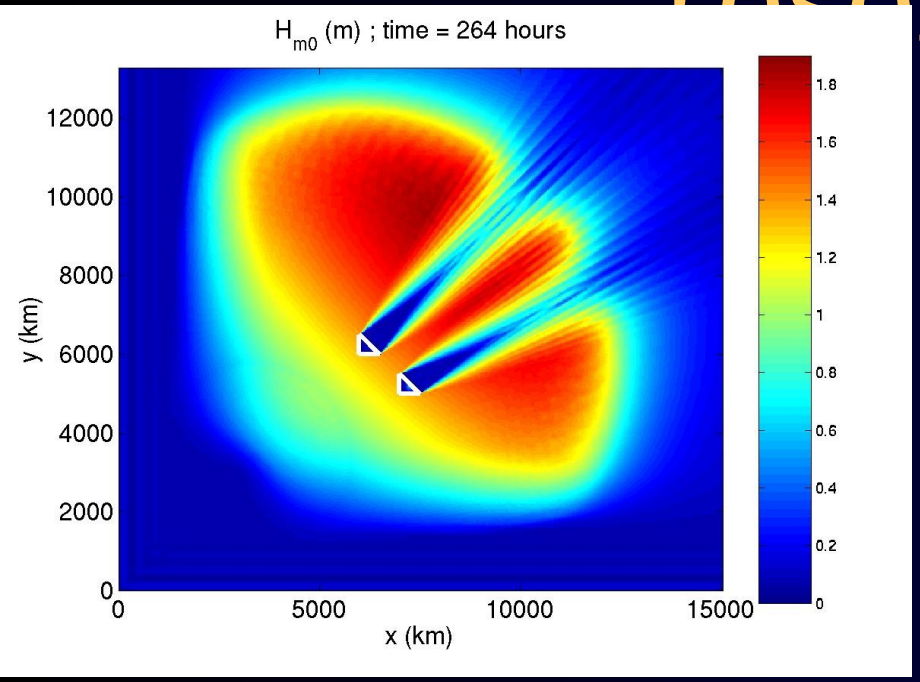


hybrid

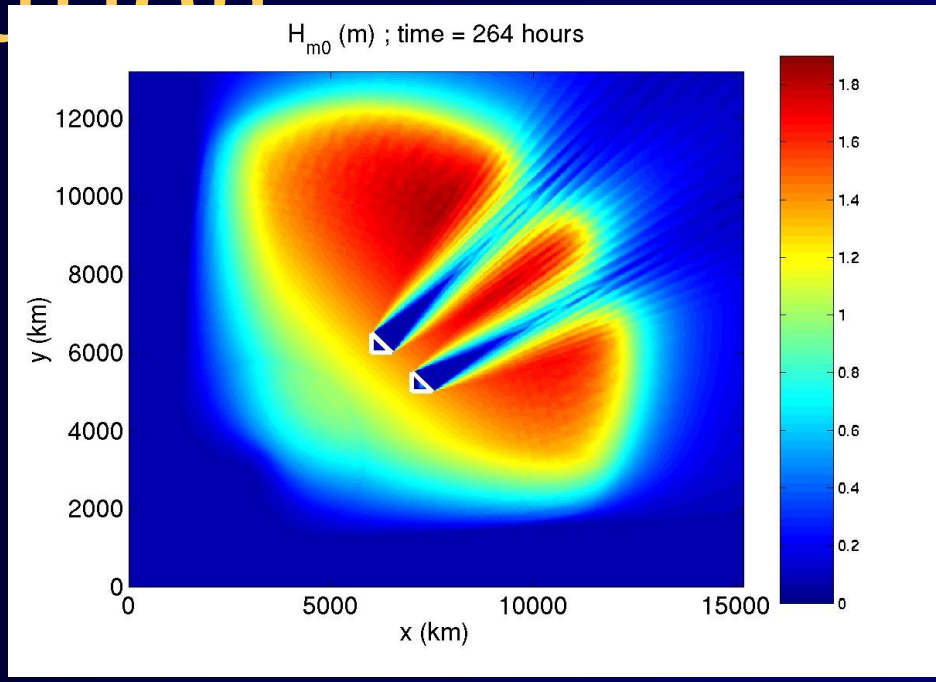


rigorous

Hybrid geographic resolution, fine spectral resolution



hybrid



rigorous

Caveats (Conclude)

- there *is* error involved with the transformation
  - minimize transformation (unconditional stability helps)
- transformation of 2 coordinates simultaneously (not all 4 yet)*
- 3rd generation source terms
- memory

Parallel SWAN

- John Cazes & Tim Campbell (PET/NAVO HPC/Stennis)
- OpenMP (no extra SWAN versions required)
- “Shared memory pipelined parallel”